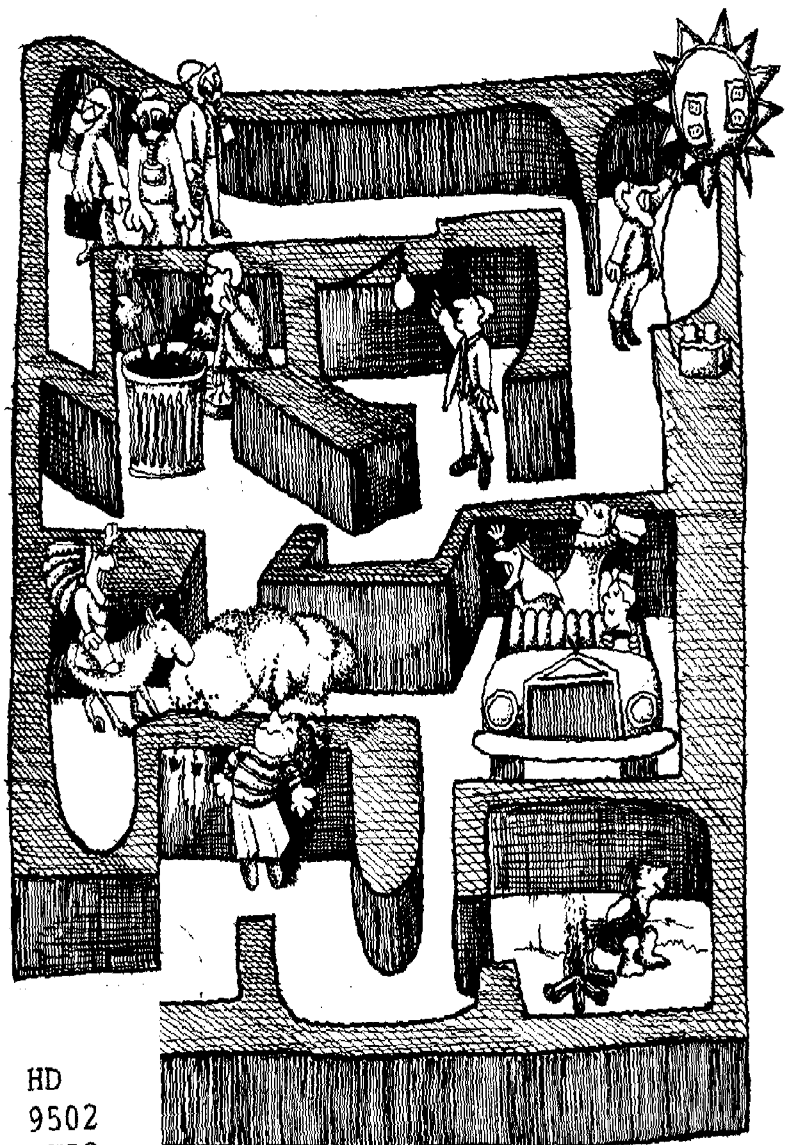
10345

Energy and the Environment

U.S. Energy Research and Development Administration



CITIZENS' WORKSHOP HANDBOOK

10345

Energy and the Environment

Citizens' Workshops are a program of the Energy Research and Development Administration

America's prosperity and high standard of living were built upon readily available, inexpensive supplies of energy. Our industrial strength, agricultural bounty, comfortable homes, fast and easy transportation of people and goods—all of these things consume high levels of energy, primarily fossil fuels.

Since fossil fuels are limited, it is clear that we will need to change both our habits of energy use and our sources of energy supply. These changes will require that the American public make a number of important choices. And to do this intelligently, the public must be better informed about the basic factors involved and their interrelationships.

The Energy Research and Development Administration (ERDA) is making a determined effort to provide American citizens with the kind of information they will need to make wise choices. The Citizens' Workshop Program on Energy and the Environment is one of the ways that ERDA is using to provide this information.

A Citizens' Workshop brings together a group of interested citizens and a knowledgeable scientist to provide an opportunity to develop national energy and environmental decisions based on individual preferences. Using the Energy-Environment Simulator (an analog computer decision-making game), citizens are able to make judgments on the use of energy resources, environmental effects, growth, and the quality of life. As in the real world, energy resources are exhaustible and alternative energy resources must be developed. In this way, participants are able to gain a better perspective on the energy problems confronting us today and the need to plan for the future.

Citizens' Workshops and other ERDA information activities make available to the public basic facts for making decisions in the whole area of energy use and conservation. They emphasize the complexities of the factors involved in energy problems and the need to take positive action toward energy conservation and the development of alternative energy sources.

Robert C. Seamans, Jr.

Robert C. Seamans, Jr., Administrator
Energy Research and Development Administration

Citizens' Workshops on Energy and the Environment

We have a number of options for meeting our present and future energy requirements, including fundamental decisions about population growth, conservation of resources, demands on energy, environmental consequences, and development of new energy technology.

The Citizens' Workshops sponsored by the Energy Research and Development Administration are designed to acquaint the public with the complexities of the energy-environment situation. They give the participants a chance to face, in a simulated situation, the same kinds of decisions encountered by real-life policy-makers, and to learn more about the complex relationships among energy demands, energy supplies, and environmental pollution.

This activity is made possible by the Energy-Environment Simulator, a computer-like device that imitates the real world. The simulator has been likened to a *time machine*, on which time speeds by at a rate of 100 years per minute. The participants must make decisions by controlling energy supplies and demands. The object of the game is to maintain a supply of fossil fuels for as long as possible and to keep the environment as clean as possible.

In addition to the time clock, the simulator has four functional areas:

1. The *Energy Supply* allows one to draw from coal, petroleum, gas, hydroelectric, nuclear and geothermal reserves. As time passes, indicator lights show the amount of reserves remaining.

2. The *Energy Pools*, either chemical or electrical, show how the resources are to be converted. Energy from

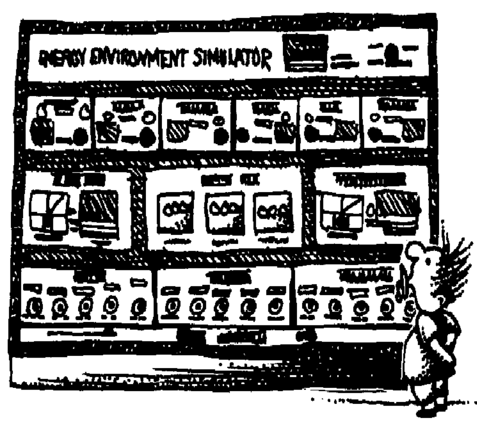
coal, petroleum, and gas can be directed into either pool; hvdroelectric, nuclear, and geothermal can only go into the electric pool. The participant chooses the distribution.

3. *Energy Demands* are divided into three major areas—industrial, transportation, and household/commercial. Energy demand grows in each area as time passes. The participants can adjust demands up or down and can control population growth and per-capita energy growth.

4. The *Environmental Impact* of the decisions are in the last section: air pollution, thermal effects, radioactive wastes, etc. The per capita energy consumption is also represented here.

From remote panels, teams of players control the outcome. There are an infinite number of outcomes, with no *correct* answers. No two groups will ever reach the same results.

The Citizens' Workshops also provide the opportunity for discussion of a wide variety of issues relating to energy and the environment. They are conducted by qualified energy specialists from across the country as a public education activity of the Energy Research and Development Administration.

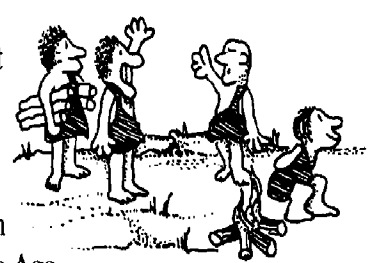


Energy and the Environment

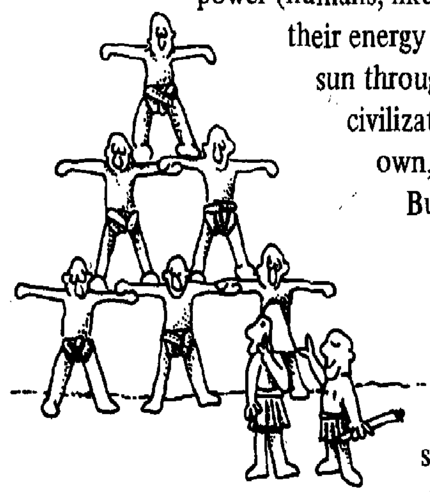
Man has been using energy since he first appeared on earth thousands of years ago. But only in the past century has man's use of energy threatened to overwhelm his environment.

Primitive man consumed energy, for the most part, in the form of food: Energy from the sun was converted by photosynthesis into the plant life which he, or the animals he hunted, ate. The earth's population was scanty and demands for energy were few.

At some time in the distant past, man discovered fire and learned to use it. But it wasn't until man learned how to create fire, perhaps while chipping flint tools and weapons, that he began the journey out of the Stone Age.



When man settled down to cultivate the land, he trained animals to work for him, and for countless centuries animals supplied most of man's energy. In some parts of the world, they still do. Men also turned to other men to meet growing energy needs: The Egyptians built their pyramids with slaves, a method of harnessing solar power (humans, like animals, receive their energy indirectly from the sun through food) that other civilizations, including our own, have relied upon. But demands for energy also tapped man's creativity. The wind was made to turn windmills and push sailing ships, and water wheels began a technology that has led to the huge hydroelectric plants of today.



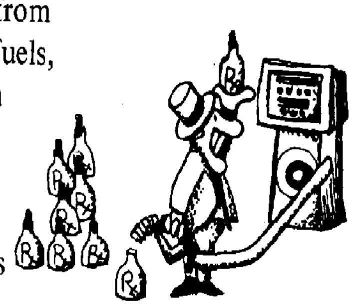
The industrial revolution brought machines for converting energy from one form to another that irrevocably changed man's life and his relationship to his environment. First came the steam engine, and then, within a short time, the internal-combustion engine—and both had relentless appetites for new fuels. Coal for the steam engine replaced wood as the primary source of energy in the industrialized societies, and as the internal-combustion engine was accepted, the demand for oil grew.

The steam engine made energy portable on a large scale for the first time: Factories no longer had to be near rivers, and locomotives and steamboats revolutionized transportation. Electricity brought new uses for the steam engine: **Less than 100 years ago, a coal-fired steam engine was joined to a generator and the first central-power-generating station turned on the lights of New York City.** Electricity is now essential to our civilization.

Petroleum products, before the internal-combustion engine, had been used mainly for patent medicines, although kerosene had replaced whale oil and candles and was beginning to be used for heating. Gasoline, however, had been a wasted by-product. Now, the millions of cars, trucks, and buses crowding our highways are all powered by internal combustion engines; so are the airplanes, ships, and trains. All of them depend on petroleum for fuel.

Another form of energy is now playing a significant role: the atom. Albert Einstein's theoretical basis for nuclear fission, $E=mc^2$, was formulated in 1905. But it was not until 1942 that scientists in Chicago, working under Enrico Fermi, created the first self-sustaining nuclear chain reaction. This new form of energy was first used for weapons–the atomic bombs that brought World War II to a devastating, but conclusive end. Following the war, however, peaceful applications of nuclear energy were pursued and 12 years later the first large-scale commercial nuclear power plant began generating electricity in Shippingport, Pennsylvania.

Today, we draw our energy from a variety of sources, primarily from running water, fossil fuels, and nuclear fission. In the past few years, however, we have been forced to realize that fossil fuels are finite and that we have been wasteful with resources that had always seemed limitless. Now, we must use these fuels more wisely and develop new sources of energy.



How Serious?

In the U. S., we use more than 30 times the energy we used 100 years ago–but the population has increased only seven-fold. This means that each American is using about four times more energy than his great-grandparents. Every person in this country uses approximately 400 million BTU's of energy each year: twice as much as a person in Great Britain, three times as much as the average French citizen, and from 10 to 100 times the amount of someone in a developing country. **We have only six per cent of the world's population, yet we consume about one-third of the world's energy.**

Energy consumption by individual Americans–and by U. S. industry–keeps going up. Just compare modern suburban homes with vintage 1949 houses. Today's are centrally heated and air conditioned, with labor-saving appliances ranging from dishwashers to electric toothbrushes. In the garage, there are most likely two cars waiting.

Since the turn of the century, we have come to rely more and more on oil and natural gas. Today, these fuels supply more than 75 per cent of our needs, which is far beyond our domestic production. Each year we import more oil and natural gas. In 1973, for example, we imported more than 35 per cent of our petroleum–an amount equal to our total consumption in 1950.

We still have large supplies of coal, but use it for less than 18 per cent of our energy. Electric power from water is limited by the lack of suitable sites; four per cent of our energy is from hydropower, a figure that is not expected to grow significantly. Within 10 years, nuclear power plants will be meeting up to 10 per cent of the demand; and by the year 2000, energy from the atom will supply more than a quarter of our energy.

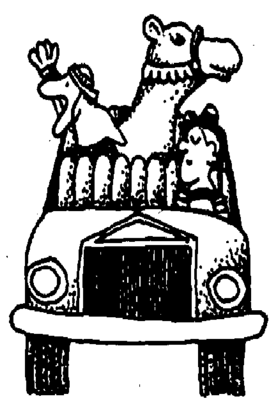
It is still early to speculate about emerging energy sources. Geothermal power provides a small part of our energy and is expected to provide slightly more in the future.

The sun, wind, tides, fusion, magnetohydrodynamics, oil shale, photosynthesis, ocean gradients, and others, are being investigated, but it will be years before any of them really begin to pay off. In the meantime, we must make do with what we have: coal, oil, natural gas, and hydroelectric and nuclear power. How we manage these resources over the next few decades is a critical question.

How Much is Left, Where is it, How is it Used?

If we had to depend solely on domestic resources, how long would they last? Estimates vary, but we know roughly how much is left.

Coal resources are estimated at 3.2 trillion tons, but coal reserves (that is, coal which can be economically recovered by present methods) are considered to be only 390 billion tons. This means, at the present rate of usage and growth, our coal reserves would last 500 to 600 years.



Natural gas has become popular because it is cheap and clean. In 1970, known reserves were reported to be 291 trillion cubic feet, with demand around 18 trillion cubic feet a year and increasing rapidly. **Unfortunately, natural gas is being discovered at a slower rate than it is being used;** U. S. reserves could be exhausted before the end of the century.

Petroleum, the mainstay of U. S. energy, meets more than 45 per cent of our energy needs. The U. S., which has oil reserves of 35-to-40 billion barrels, uses more than 14 million barrels each day. Estimates of undiscovered, economically recoverable oil range from 60 billion to 400 billion barrels.

Seven per cent of our petroleum, 18 per cent of our natural gas and 65 per cent of the coal we use is burned to generate electricity. Other methods of generating electricity are hydropower, nuclear fission reactors, and geothermal power. Hydroelectric power furnishes about four per cent of our electricity, a proportion that will remain stable until the end of the century, when most of the suitable river sites will have been dammed.

There are few geothermal sites in the U. S., most of them in the West, and only one has been developed. But even when all available sites are in use, geothermal power will provide less than one per cent of our energy.

Nuclear energy now supplies about one per cent of our total energy demands, but is expected to provide far more by the end of the century. Within ten years, more than 200 nuclear plants will be generating some 200 million kilowatts. There is enough known uranium-235 in the U. S. to last about 40 years at projected usage rates, and more is expected to be found. Breeder reactors, which produce more fuel than they consume, should be available in another 10 years. Uranium-238 reserves are adequate for about a thousand years for the breeder reactor.

By the year 2000, we will be using about three times more energy than we are now. Barring unforeseen technical advances, this expansion must be met by the five basic sources–coal, oil, gas, nuclear power, and hydropower.

How are we using all this energy? More than 40 per cent keeps our industries running; 25 per cent is used for transportation (over half of this is used to move people). Thirty-three per cent of our energy is used in commercial and residential buildings, primarily for heating and air conditioning.

If we were able to extract all the energy that is actually contained in fossil fuels, we could drastically cut the rate we use them. As it now stands, however, we only use half of their energy content and waste the other half.

Let's follow a ton of coal (2000 pounds) from the mine to the electric plant to the homes and offices where it is eventually consumed as electricity. First of all, 42 per cent of the coal never leaves the deep mine; it is either lost in the mining process or it is too difficult and costly to get out of the ground. By comparison, only 20 per cent of the coal is lost in strip-mining, which is one reason stripping has become so widespread. This means that from a ton of coal that is actually in the ground, only 1140 pounds is removed from a deep mine and 1600 pounds from a strip mine.

Another eight per cent is lost in processing the coal and an additional one per cent in transporting it from mine to power plant. By the time it reaches the plant, therefore, only 1040 pounds of coal from the deep mine and about 1450 pounds from the strip mine remain from the original ton.

When the coal is burned, some 62 per cent of the energy in the coal that actually reached the plant is lost. In other words, the power plant can make good use of only 38 per cent of the energy in the coal. Of the ton we started with, therefore, we have been able to extract the energy equivalent of only 400 to 550 pounds of coal. And it has not yet arrived at its destination as electricity: As it travels through transmission lines, another 10 per cent or more of potential energy is lost.

To make things worse, additional energy is lost once the electricity is put to work. In lighting, for example, less than 10 per cent of the energy is realized. The result is that the equivalent of only 50 pounds of coal energy is actually converted to useful work from the original 2,000 pounds in the ground—less than three per cent.

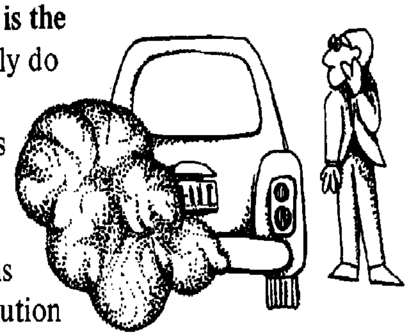
The situation is not much better with other fuels. Whether we use oil, natural gas, or nuclear fuel to generate electricity, there are inefficiencies all along the line. If we can figure out ways to increase the efficiency of our existing energy systems, we could save a substantial amount of our resources.

the Environment

There is no such thing as an environmentally neutral energy system. Whenever we flip a light on or start a car, we affect the environment in some way: disruption of the land, creation of solid waste, air or water pollution, or a combination. Even a windmill diverts land from other uses.

Most energy is produced by burning fossil fuels, and whenever combustion takes place, pollutants are released into the atmosphere: carbon monoxide, sulfur dioxide, oxides of nitrogen, unburned hydrocarbons, and ash. Millions of tons of these pollutants are disgorged into the air each year as a result of using energy.

The automobile is the biggest polluter. Not only do automobiles and trucks pour enormous amounts of pollutants into the air, but they contribute indirectly to other forms of pollution: Water pollution from oil spills and refinery discharges, and land disruption from pipelines and oil wells are part of the automobile system.

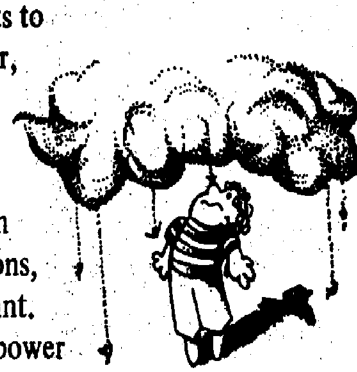


Even a hydroelectric plant, the cleanest large-scale producer of energy we have, causes environmental damage by flooding thousands of acres of land when water backs up from the dam. Electric power seems clean and non-polluting at the point of use, but the system that produces electricity creates pollution at various stages, regardless of the fuel used to generate it.

Look at a 1,000-megawatt coal-fired electric power plant, for example. Part of the environmental price we pay for such a plant depends on whether the coal it burns is taken from a deep mine or a strip mine. **A deep mine requires some 9,000 acres to produce enough coal to keep the plant operating; a surface mine requires 14,000 acres.** Additional land is displaced for the plant that processes the coal, for the highway or railroad that transports it to the power plant, and for the electrical generating plant itself. On an average, 17,000 more acres are needed for right-of-way for the transmission lines. (This is the same for all types of power plants.) Altogether, a coal-fired plant uses up some 30,000 acres, or about 50 square miles.

Some water pollution also occurs as a result of producing electricity from coal, both from the mining process, and, in the form of thermal pollution, from the conversion process. Air pollution, however, is the most serious environmental consequence of a coal-fired plant. Without emission controls, a 1,000-megawatt plant produces more than 350,000 tons of pollutants each year; two-thirds is fly-ash, but more than 100,000 tons are toxic sulfur dioxide, carbon monoxide and nitrogen oxides. Using present emission control devices, these pollutants can be reduced to less than 50,000 tons annually. But, more than 900,000 tons of solid wastes are created as a result of these controls, requiring 15 acres a year to dispose of it.

An oil-fired electric power plant of the same size is not as harmful to the environment as one that burns coal. Even though it takes a thousand on-shore oil wells, for example, much less land is needed to produce fuel for the plant. Overall, an oil-fired system requires two-thirds of the land area of a coal-fired system, and most of that is for transmission lines. Air pollution is also considerably less in an oil-fired power plant. Without any controls, this amounts to about 150,000 tons a year, mostly sulfur dioxide, nitrogen oxides, and carbon monoxide. With emission controls, this can be cut to under 40,000 tons, a little less than a coal plant.



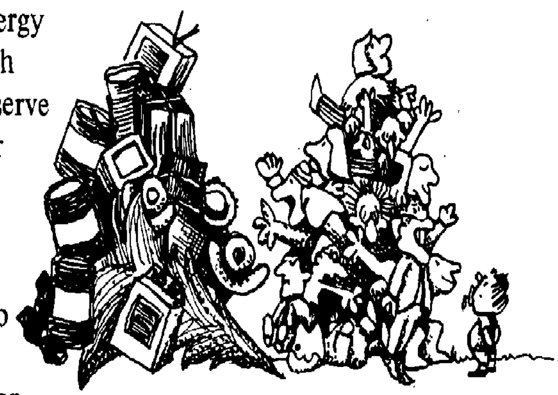
Natural gas-fired power plants cause less environmental disruption than any other fossil-fuel plant. Emission of pollutants into the air from a gas-fired plant, without emission controls, is only a fraction of that from coal or oil-fired plants with emission controls.

Some by-products of combustion are potentially dangerous: They create smog, darken the skies, blot out the sun, and are generally unhealthy. **High concentrations of nitrogen oxides and sulfur dioxide in the atmosphere have been linked to respiratory illness and higher death rates.**

With hydroelectric and nuclear power plants, such emissions are not present. Nuclear plants do emit small quantities of low-level radiation into the atmosphere, but their most significant environmental problems are radioactive solid wastes and the discharge of heated water into rivers and lakes, which raises the temperature of the water, which, in turn, affects the fish and plant life. A 1,000-megawatt nuclear power plant produces approximately 100 cubic feet of radioactive wastes each year, which must be carefully stored for thousands of years. By the year 2000, it is estimated that radioactive wastes from nuclear power plants in this country will amount to 500,000 cubic feet, enough to cover a city block to a depth of about 10 feet.

Our environment is being adversely affected by energy production and use. As our population grows and our energy demands go up, the situation will get worse. Remedies are costly: Pollution control devices on automobiles, for example, increased the cost of automobiles and reduced the efficiency of their engines. So, a measure to protect the environment not only made cars more expensive, it increased energy consumption. Emission control devices for electric power plants have, in turn, increased the cost of electricity.

How, then, are we going to accomplish these two important objectives: First, to provide energy for economic growth and, second, to preserve the environment for ourselves and for future generations? How are we going to maintain a balance between our need for energy and our desire for a clean environment? Measures can be taken to help achieve these goals. They involve population growth, conservation of resources, and development of new energy systems.



Population

Each day, the average American uses the energy from 13.6 pounds of coal, 3.3 gallons of oil, 297 cubic feet of natural gas, 3.7 kilowatt hours of hydroelectric power and .7 kilowatt hours of nuclear power. A baby born today will consume during his lifetime, 175 tons of coal, 2000 barrels of oil and 7.5 million cubic feet of natural gas. And that's based on today's rate of consumption–a rate that is growing steadily.

Simple arithmetic tells us that if the population continues to grow, we will be using considerably more energy. The U. S. birth rate has leveled off; but even so, the population continues to grow. At the present rate, the population will not stabilize until it reaches 275 to 300 million.

In other parts of the world, particularly in the developing areas, populations are growing rapidly and each new baby further strains already inadequate energy resources. Thus, if developing areas are to grow economically, it seems clear that they must first deal with the population problem. But the rich nations, too, must control population growth. If not, there simply will not be enough energy to go around, unless per capita energy consumption is held steady or reduced–and that seems unlikely.

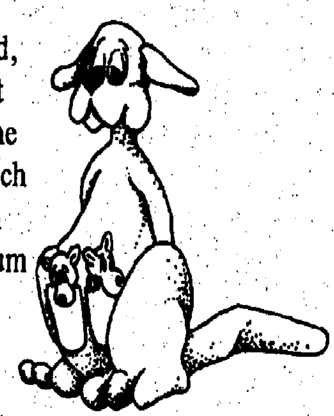
Conservation

Energy in the U. S. has been cheap and the result has been waste. How many times have we walked out of a lighted room without bothering to turn out the lights? Or driven a couple of miles to pick up an unimportant item? These days of waste seem to be over now, as shortages and higher prices teach us a hard and important lesson: **We must learn to conserve energy and use it more wisely or we're going to be in serious trouble.**

Fortunately, proper conservation measures can help extend our energy supplies far into the future.

We must learn, for example, how to make our electric system more efficient, from start to finish. We are recovering less than 80 per cent of the coal and 40 per cent of the petroleum from our mines and wells. We must recover more. Once these fuels reach the power plant, less than 40 per cent of their potential energy is converted to electricity. We must do better. Almost 10 per cent of the energy is lost over the transmission lines, but methods, though costly, are available for reducing this almost to zero. More efficient plants would also significantly reduce pollution.

Many industries could use energy better. By changing the way utilities charge for electricity, to encourage conservation by industry rather than high usage, would make saving energy profitable. It is estimated, for example, that seven per cent of our total energy is used by the aluminum industry. It takes much less energy to recycle aluminum than it does to produce aluminum from ore. Thus, higher energy costs would not only reduce industrial consumption, but it might also have the happy result of getting beer cans off our roadsides.



Substantial energy could be saved in transportation. Automobiles, trucks and other forms of transportation could be made to use fuel more efficiently—the average American car gets 12 miles a gallon. By building smaller and better cars, this could be doubled.

In the effort to save gasoline, the individual motorist can take some significant steps:

- **Use public transportation**
- **Form car pools**

Test Your E.Q.*

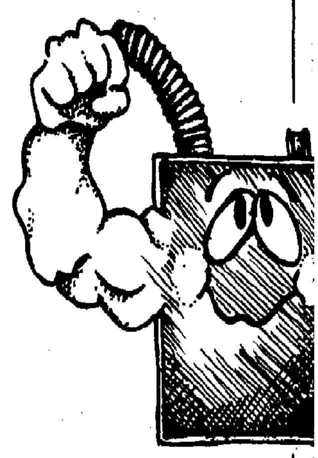
1\. —— How much of the energy used in gas stoves supplies the pilot lights?
a. 10%
b. 25%
c. 50%

—— 2. An incandescent lamp and a fluorescent lamp having the same light output: Which uses energy more efficiently?
a. fluorescent
b. incandescent
c. both about the same efficiency

—— 3. How many soft drink cans can be manufactured from recycled aluminum with the energy needed to make a single can from aluminum ore?
a. three
b. five
c. twenty

—— 4. How long would a 100-watt light bulb burn on the energy needed to manufacture one throw-away soft-drink can or bottle?
a. 10 minutes
b. 5 hours
c. 20 hours

—— 5. How much of the energy stored in crude petroleum is lost between the oil well and a moving car?
a. 20%
b. 60%
c. 90%



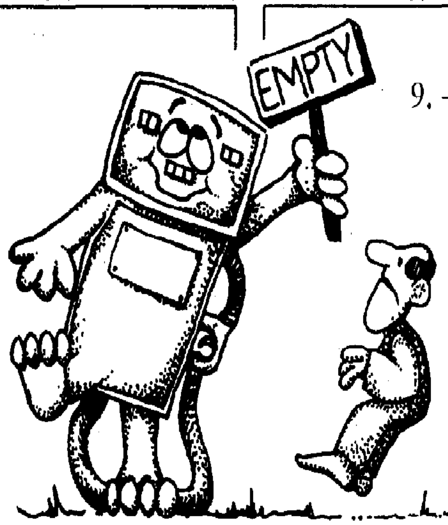
——6. The heat energy of a gallon of gasoline is equivalent to
a. 5 man-days of labor
b. 15 man-days of labor
c. 25 man-days of labor

* *Energy Quotient.*

Take this quiz to check your knowledge and understanding of energy-environment issues. When you have marked your answers, turn to page 24 to see how well you have done.

—— 7. How much faster than their rate of production are we consuming our fossil fuels?

a. 10 times
b. 1,000 times
c. 1,000,000 times



—— 8. What fraction of the world's energy consumption occurs in the U. S.?

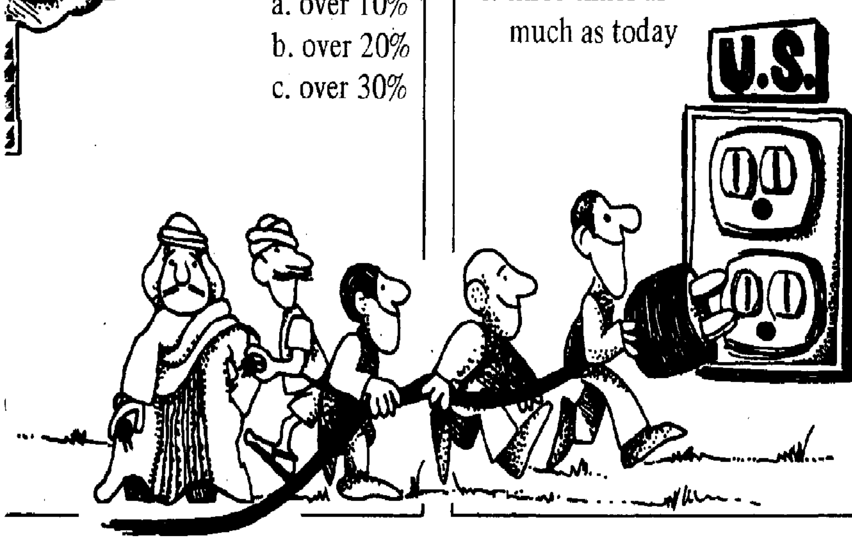
a. over 10%
b. over 20%
c. over 30%

9. —— Which of the following fuel resources is in greatest danger of exhaustion?

a. coal
b. petroleum
c. natural gas

—— 10. In the year 2000, American total energy demand will be:

a. the same as today
b. twice as much as today
c. three times as much as today



—Drive at reasonable speeds; no fast stops and starts;

do not race the engine; do not leave the engine idling for long periods.

—Keep trips to a minimum; consolidate shopping trips and other errands.

—Keep the car engine well tuned.

In our homes and commercial buildings there are ways to make important savings. Construction standards need to be changed; for example, proper insulation could save up to 50 per cent in home heating costs and air conditioning. Most commercial buildings have been over-heated, over-cooled, and over-lighted. Better architectural design could reduce commercial heating and lighting demands by using less glass, better insulation, and appropriate heating and lighting systems.

Significant amounts of energy can be saved in houses and apartments, too:

—Install weather stripping on doors and windows.

—Install storm doors and windows.

—Have the furnace checked and cleaned regularly.

—Close the fireplace damper when not in use.

It has been estimated that turning all thermostats down two degrees in the winter and raising them two degrees in the summer could save more than half a million barrels of oil a day by 1980. The winter of 1973-74 showed us that we did not have to keep our homes nearly as warm as in the past, and that by wearing a sweater indoors we could still be comfortable.

Household appliances also use a lot of energy, some of it unnecessarily. In fact, as much as 10 per cent of the gas used in this country is burned by pilot lights. Much of this could be saved by replacing pilot lights with ignition devices.

There are other ways of conserving energy on home appliances and lighting:

–Use cold water in the washing machine.

–Do not wash dishes under hot running water.

–Repair leaky faucets.

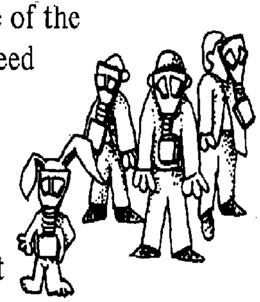
–Forego the luxury of frost-free refrigerators and freezers.

–Install fluorescent lamps instead of standard light bulbs.

–Turn off lights when not in use.

Other Sources of Energy

One thing is quite clear: Unless we develop alternative energy sources, we will exhaust our fossil fuels sooner rather than later. To make things worse, even if abundant fossil fuels were available, it is doubtful that the environment could absorb the ever-increasing amounts of pollution their burning would create. In some of our major cities we can hardly breathe the air now. For the sake of the environment, as well as for the need of a reliable energy supply, we must find other sources.



One of the key criteria for new energy sources is that they not pollute the environment unnecessarily. A number of alternative energy sources are presently being developed that may, perhaps, supply the energy of the future.

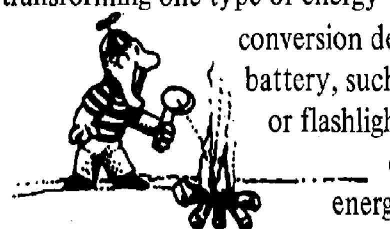
Energy for the Future

For the foreseeable future, our energy will come from present sources—coal, oil, gas, nuclear fission, and hydroelectric power, although the portion provided by each will change as nuclear fission takes over a large share. New energy technologies may be developed by the end of the century, but it's doubtful they could be supplying significant amounts of energy by that time.

There are a number of possible technological combinations for providing energy in the future. In addition to new technologies, there are better ways to use existing energy sources. Here are some of the possibilities for the future.

Direct Conversion

Direct conversion offers a number of possibilities for transforming one type of energy to another. The direct



conversion device we know best is the battery, such as the one in our automobile or flashlight, which converts chemical energy directly to electrical energy, with no moving parts. Batteries do not create energy, however, they only store it and furnish it when needed. As we all know, they must be recharged.

The solar cell is another method of direct conversion. Solar cells are used extensively in the space program, but high costs have prevented their commercial use. In time, their cost may be cheap enough that the roof of every home will be implanted with solar cells. Sunshine would be absorbed by these cells and converted into electricity, which would be fed into a bank of storage batteries, which could supply a home's electric needs. Similar systems on a much larger scale could possibly be used to power office buildings and, perhaps, factories.

The fuel cell is a close relative of the battery. It, too, converts chemical energy directly to electrical energy; but, unlike the battery, it has a continuous fuel supply, such as hydrogen and oxygen. Unfortunately, fuel cells are too expensive for general use. But if manufacturing costs can be reduced, they might become important, which would be a happy turn of events, since the fuels they use are plentiful.

Storage batteries may become useful adjuncts to new energy systems. For example, a solar power system in a home would require efficient batteries to store energy from sunshine for use during the night or on cloudy days. Also, new types of long-life batteries may eventually power automobiles.

Of the direct conversion methods we know, the one that shows most promise for large-scale energy production is magnetohydrodynamics (MHD). MHD is a method for generating electricity by passing hot combustion gases from fossil fuels through a magnetic field at high speed. The extremely high temperatures needed to convert the fuel to plasma, however, have created engineering problems and delayed development of MHD demonstration plants. A major advantage of MHD plants is that they could probably be operated at 50 to 60 per cent efficiency—significantly higher than conventional plants. The MHD process would also significantly reduce emissions from coal and oil.

Energy from Waste

There have been several proposals over the years for generating energy from waste, which would help solve two problems: what to do with the waste and how to generate more power. One possibility, which is being used already in some cities, is to burn waste in power plants; shredded garbage can be mixed with coal or oil to fuel specially designed plants,

or converted coal-fired plants. In the long run, such plants may be more useful for waste disposal than for generating electricity. **But right now, there is just not enough suitable waste to make much of a dent in the energy shortage.** The same holds true for methods of producing methane, the primary ingredient of natural gas, from agricultural wastes or sewage. These proposals are not yet economical in large-scale plants, although they may be useful in individual situations.

Oil Shale and Coal

There are vast deposits of oil shale and coal in the U. S., and pilot projects are under way for the extraction of oil from shale and in coal gasification and liquefaction. Gas from coal can substitute for natural gas. In fact, gas from coal was at one time widely used in the U. S., although the processes used to gasify the coal were crude and inefficient. It can be transported through existing pipelines (although not for great distances), and one major advantage is that the sulfur and many other pollutants in coal are removed in the gasification process.

Converting coal to liquid is more complicated and expensive, but it has been proven technologically. The liquid hydrocarbons from coal can be transported through existing oil pipelines and refined, like petroleum, into a variety of products.

There are about 2 trillion barrels of oil locked in the oil shale in the West, enough for years to come. Until recently, however, extraction of oil from shale has been too expensive; but now, with higher prices, oil from shale appears more practical.

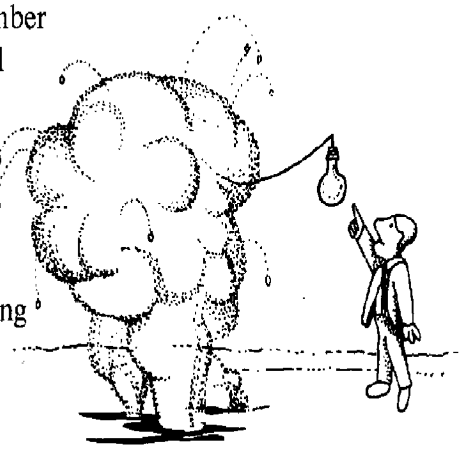
Mining oil shale will cause extensive physical damage to the land. It takes 1.5 tons of shale to produce one barrel of oil, which means thousands of acres of our most beautiful land must be mined. Shale processing also releases large quantities of noxious hydrogen sulfide and other pollutants, and millions of gallons of water are needed to process the enormous quantities of rock. Water is scarce in shale areas and water pollution as a result of shale mining could become serious.

In view of their serious environmental effects, new coal technology and oil shale recovery are obviously not panaceas. Until ways are found to protect the environment while mining and processing these fuels, they cannot be fully exploited.

Geothermal

There is only one commercial geothermal plant in the U. S., although geothermal energy furnishes a major part of Iceland's power, and is used in Italy, New Zealand, Japan, Mexico, and the Soviet Union. The principle is simple: Harness the energy from the interior of the earth, either as steam or superheated water (as in a geyser), or from heated rocks in the earth's crust.

There are a number of potential geothermal sites in the U. S., most of them in the West. If all were exploited, according to some estimates, geothermal plants could be supplying an important share of our energy by the end of the century.



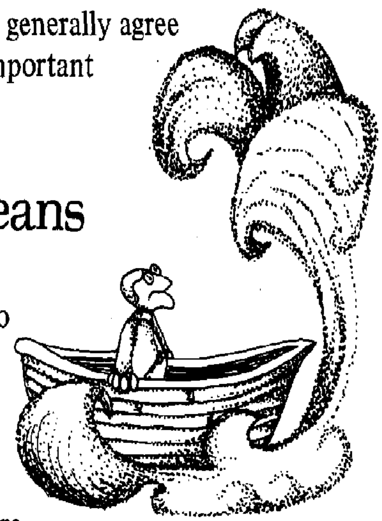
These estimates appear overly optimistic to some critics, who believe the environmental effects of geothermal energy have also been neglected. A large geothermal plant, it is true, could release more sulfur emissions into the air than a coal-fired plant of comparable size. Water from geothermal sites also contains harmful salts and other chemicals and there is, in addition, the potential for land subsidence caused by the extraction of large quantities of water.

Solar

Solar energy is among the most promising sources of energy for the future. Scientists have offered a variety of proposals for harnessing this limitless and virtually non-polluting energy source. (The storage rooms of the Smithsonian Institution in Washington, D. C., are filled with intriguing, long-forgotten inventions using the sun's heat for energy.) These suggestions range from giant desert solar farms to huge satellites orbiting the earth, beaming the sun's energy back to receiving stations.

Most of these large-scale projects are far in the future, but more modest applications of solar energy have been used for years. There is plenty of room for expanding these systems, with considerable energy savings: **Solar energy for water heating and space heating, for example, is widely used in Japan, Israel, and Australia.** In this country, most individual solar units used earlier in California and Florida have been displaced by the introduction of cheap alternatives, such as electricity and gas. Only a few houses in the U. S. now use solar energy for appreciable amounts of their energy requirements. It is now becoming economical to install solar equipment in residences, apartments, office and commercial buildings for heating, air conditioning and hot water. These systems generally consist of a large surface, or *collector* for

absorbing the sun's heat and transferring it by fluid in pipes to a storage area. From the storage area the system provides space heat, hot water, or (with a heat pump) air conditioning. Scientists generally agree that solar energy will be important in the long run.



Winds and Oceans

It sounds quixotic to suggest that we return to windmills for energy. But this age-old means of capturing the wind is again being taken seriously.

Only certain sites are suitable: The Great Plains and the coasts, for example, have stronger, steadier winds. But even if all sites were put to use, wind could not produce significant energy, and huge steel towers, with 50-to-100 foot blades, would clutter the landscape. Windmills would, however, be a non-polluting way to generate electricity.

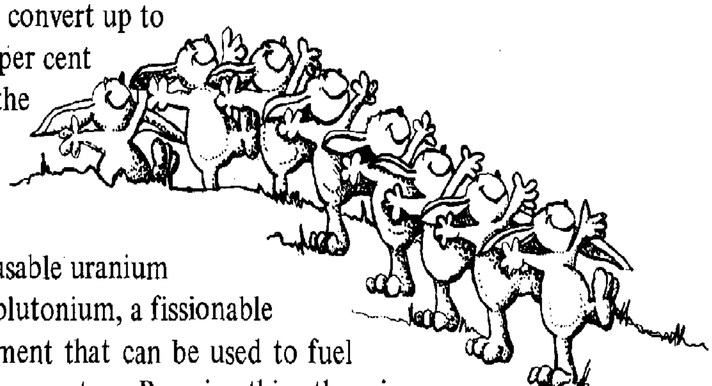
The oceans are another potential source. Tidal power, for example, can be put to use where the difference between high and low tide is substantial. There is only one commercial tidal-electric plant in operation in the world, on the coast of France. In the U. S. a few sites are feasible for such projects, among them the Bay of Fundy, where a tidal plant has been on the drawing boards for 50 years. Unfortunately, the proposed plant has never been proven practical. In time, perhaps, a few such plants will be in operation, generating a fraction of our energy needs.

Several other possibilities offer hope for tapping the energy potential of the oceans. One is to take advantage of the temperature differences between the surface of the ocean and the deeper waters, using heat engines designed to operate across these thermal gradients. Though not yet commercially practical, this type of energy could, in time, provide a large share of our requirements.

Nuclear Power

In the U. S., we have been using electricity from nuclear plants since 1957; they are now supplying about two per cent of our energy and over six per cent of our electricity. Between now and the year 2000, nuclear power is expected to take up much of the slack created by shortages in other power sources.

One of the most promising developments in nuclear fission technology is the breeder reactor, which actually produces more nuclear fuel than it consumes. Conventional reactors use uranium for fuel, but less than one per cent of this fuel can be used in the controlled nuclear reaction that produces the heat needed to generate electricity. A breeder reactor, however, can convert up to 90 per cent of the



unusable uranium to plutonium, a fissionable element that can be used to fuel other reactors. By using this otherwise wasted uranium, the breeder offers a fuel supply that could last for centuries. An experimental breeder plant is now being built in Oak Ridge, Tennessee. It is expected to be in operation by the early 1980's.

Safety is a major consideration in nuclear power. There is no chance of a nuclear power plant exploding like a bomb, but the leakage of low-level radioactivity is a hazard.

Nuclear power plants are designed with safety features to keep this leakage well within safe limits.

The **transportation, storage, and disposal of radioactive materials is one of the gravest social responsibilities mankind has ever assumed.** We have accepted the responsibility for protecting ourselves and generations to come from the effects of radiation. No one has been injured by radiation from a nuclear power reactor. The chances that a nuclear reactor could have a serious accident in any given year are extremely slight, but additional safety measures are being developed to reduce these odds still further.

Of all the possible energy sources on the horizon, the one that holds most hope for the future is nuclear fusion. Its power comes from the same process by which energy is generated by the sun. If it can be controlled, fusion will supply us with a safe, cheap, non-polluting, virtually inexhaustible source of energy. But even the more optimistic scientists believe it will be 25 years, at least, before fusion power will be available.

ANSWERS:

Score 1 for each correct answer.
0–5 Poor, 6–7 Fair, 8–10 Good.

1. (c) Approximately half of the gas used in a gas stove is used to fuel the pilot lights because pilot lights burn continuously.

2. (a) Fluorescent lights give off three to four times as much light per watt of electricity used as incandescent lamps do. One 40-watt fluorescent light gives more light than *three* 60-watt incandescent bulbs (and the annual savings may be as much as $10).

3. (c) Aluminum is a very energy intensive material with the largest share of the energy going to process the ore. Recycling is a great energy saver. The nation's total throwaway containers equivalent energy waste is equal to the output of 10 large nuclear power plants.

4. (b) A 100-watt lamp could burn for 5 hours on the energy used to manufacture a disposable can or bottle.

5. (c) Ninety-four per cent of the energy in the gasoline from crude petroleum is lost in making your car move. The efficiencies of the most important steps where energy is lost are:

producing the crude oil	96%
refining	87%
gasoline transport	97%
engine thermal efficiency	29%
engine mechanical efficiency	71%
rolling efficiency	30%

The total efficiency of the system is found by multiplying the six factors together: 6%.

6. (b) 15 man-days of labor. Said in another way, one barrel of oil contains heat energy equivalent to the energy of a man at hard labor for 2 years.

7. (c) In less than 500 years man will have consumed essentially all of the coal, oil, and gas that nature started forming 500,000,000 years ago. By comparison, that same fraction of a calendar year is approximately 30 seconds.

8. (c) More than a third of the world's energy is consumed by the 6% of the world's population residing in the United States.

9. (c) Natural gas reserves in the U. S. are expected to be exhausted in about 40 years. Petroleum should last for a century. Coal, 500 years or so.

10. (b) For more than a century, American demand for energy has doubled, on the average, every 20-25 years.

For More Information

Recent publications on energy and the environment which you might find of interest:

Allen Hammond, William Metz and Thomas Maugh, *Energy and the Future* (Washington: American Association for the Advancement of Science, 1973).

U. S. Council on Environmental Quality, *Energy and the Environment* (Washington: U. S. Government Printing Office, 1973).

Congressional Quarterly, *Energy Crisis in America* (Washington: Congressional Quarterly Service, 1973).

W. Wilson and R. Jones, *Energy, Ecology, and the Environment* (New York: Academic Press, 1974).

Exploring Energy Choices: A Preliminary Report (Washington: Ford Foundation, Energy Policy Project, 1974).

Sam H. Schurr (ed.), *Energy, Economic Growth, and the Environment* (Baltimore: Johns Hopkins Press, 1972).

"The Energy Crisis: Reality or Myth," *Annals of the American Academy of Political and Social Science* (Vol. 410), November 1973.

Nuclear Power and the Environment (Vienna: International Atomic Energy Agency, 1973).

U. S. Department of the Interior, *United States Energy: A Summary Review* (Washington: U. S. Government Printing Office, 1972).

U. S. Department of the Interior, *United States Energy Through the Year 2000* (Washington: U. S. Government Printing Office, 1972).

Science (Vol. 184), April 19, 1974 (Special issue on energy).

These organizations can furnish information about energy.
Most provide books and other materials, films, and speakers on request.

American Gas Association
1515 Wilson Boulevard
Arlington, Virginia 22209

American Petroleum Institute
1801 K Street, N. W.
Washington, D. C. 20006

American Public Power Association
2600 Virginia Avenue, N. W.
Washington, D. C. 20037

Atomic Industrial Forum
475 Park Avenue South
New York, New York 10016

Ecology Forum
124 East 39th Street
New York, New York 10016

Edison Electric Institute
90 Park Avenue
New York, New York 10016

Energy Information Center
505 King Avenue
Columbus, Ohio 43201

National Audubon Society
1130 Fifth Avenue
New York, New York 10028

Office of Public Affairs
Energy Research and
Development Administration
Washington, D. C. 20545

Sierra Club
1051 Mills Tower
San Francisco, California 94104

U. S. Department of Interior
18th and C Street, N. W.
Washington, D. C. 20240

U. S. Environmental Protection Agency
401 M Street, S. W.
Washington, D. C. 20460

U. S. Federal Energy Administration
Old Executive Office Building
Washington, D. C. 20500

Important Energy Words

Atom—The basic building block of all matter, an atom is the smallest particle of a chemical element (such as iron, hydrogen, gold, or uranium) that still has the properties of that element.

Barrel—Although seldom put in actual "barrels," crude oil is measured in a unit called the barrel, equal to 42 U. S. gallons. One barrel of crude oil has the same energy as 350 pounds of coal.

Breeder Reactor—A nuclear reactor that makes more nuclear fuel than it uses, by changing certain atoms that will not split into atoms that will split.

British Thermal Unit (BTU)—The amount of heat necessary to raise the temperature of one pound of water 1° F.

Coal—A solid fuel, mostly carbon, formed from the fossils of plants living hundreds of millions of years ago.

Coal Gasification—A chemical process to change coal into a fuel similar to natural gas; the biggest advantage is that sulfur and other pollutants in coal can be removed before it is burned.

Coal Liquefaction (Coal Hydrogenation)—A chemical process to change coal into liquid fuels similar to gasoline and kerosene; compare with *coal gasification.*

Coolant—Anything pumped through a nuclear reactor to cool it or absorb the heat it produces. Common coolants are water, air, helium, and liquid sodium metal.

Critical Mass—The smallest amount of nuclear fuel, like uranium, that will sustain a nuclear chain reaction of splitting atoms.

Crude Oil—Liquid fuel formed from the fossils of animals and plants at the bottom of ancient seas; petroleum as it comes from the ground.

Deep Mining—Mining that must be performed by digging underground shafts and tunnels.

Direct Energy Conversion—The process of changing any other form of energy into electricity without machinery that has moving parts. For example, a battery changes chemical energy into electricity by direct energy conversion.

Efficiency, Thermal—A measurement of how efficiently any device changes heat into another energy form. For example, a modern coal-burning electric plant has about 38 per cent thermal efficiency because just under 4/10 of the heat from burning the coal is actually changed into electricity.

Energy—The ability to do work or to make things move.

Fission—The splitting of the nucleus (or center) of one atom into two or more smaller atoms; fission often releases large quantities of energy.

Fission Products—The smaller atoms formed when atoms fission or split.

Fly Ash—Tiny particles of solid ash in the smoke when fuels such as coal are burned.

Fossil Fuels—Coal, petroleum, and natural gas; this term applies to any fuels formed from the fossils of plants and animals that lived eons ago.

Fuel—Anything that can be burned or fissioned to produce heat energy.

Fuel Cell—A device similar to a battery in which fuels such as hydrogen gas or methane can be directly combined with oxygen to produce electricity and very little heat; the principal by-products of the process are water or carbon dioxide.

Fusion—The process of combining the nuclei or centers of two light atoms to form a heavier atom; fusion can release great quantities of energy. The sun produces its energy by fusion.

Gas Cooled Reactor—A nuclear reactor that is cooled by a gas like air or helium, rather than by water or other liquid.

Gaseous Diffusion—A process by which natural uranium is enriched and becomes a better nuclear fuel.

Geothermal Energy—Heat energy produced deep within the the earth largely by radioactive materials that occur there naturally.

Geothermal Steam—Steam formed by underground water seeping through hot rocks deep beneath the earth's surface.

Horsepower—A unit that measures the rate at which energy is produced or used. A man doing heavy manual labor produces energy at a rate of about .08 horsepower.

Kilowatt—A unit that measures the rate at which energy is produced or used. Ten 100-watt lightbulbs use energy at the rate of one kilowatt (equal to 1000 watts). A rate of one kilowatt maintained for one hour produces or uses one kilowatt-hour of energy (equal to 1000 watt-hours).

Magnetohydrodynamics (MHD)—Process that uses a magnetic field to produce electricity directly from the hot smoke and gases we get from burning fuels like coal and oil.

Megawatt—Unit to measure the rate at which energy is produced or used; it is equal to 1000 kilowatts (see *kilowatt*).

Moderator—Material, such as water and graphite, used in a nuclear reactor to slow the speed of neutrons produced when atoms split.

Natural Gas—Gaseous fuel formed from the fossils of ancient plants and animals; often found with crude oil.

Natural Uranium—Uranium as it is found in the ground; a mixture of two types of uranium atoms. Less than one per cent of the atoms in natural uranium are the kind that will produce energy in a nuclear reactor.

Neutron—A tiny particle, extremely heavy for its size, often found in the nucleus of an atom. Neutrons have no electrical charge, and are released when atoms split (fission).

Nuclear Power—The energy produced by splitting atoms (such as uranium) in a nuclear reactor.

Oil Shale—Rock formed by silt and mud settling to the bottom of ancient seas that contains a substance similar to crude oil. So-called *shale oil* can be removed from the rock by heating and then used to make gasoline, kerosene, etc.

Petrochemicals—Chemicals removed from crude oil at the refinery and used to make a wide range of products such as plastics, synthetic fibers, detergents, and drugs.

Petroleum—See *crude oil.*

Photosynthesis—The process by which green plants convert sunshine into chemicals.

Plutonium—A heavy, man-made, radioactive metal that can be used for fuel in a nuclear reactor.

Radioactivity—A spontaneous change in the nucleus or center of an atom, accompanied by the release of energy called nuclear radiation.

Solar Energy—The energy received from the sun. Nuclear and geothermal energy are the only presently available energy forms not derived from the sun.

Solar Power—Electricity, heat, or other useful energy produced from sunshine.

Steam Electric Plant—An electric power plant (either nuclear or one that burns coal or other fuel) in which heat boils water into steam, the steam is used to turn a turbine, and the turbine turns a generator to produce electricity.

Strip Mining—Mining for coal or useful ores by removing the soil and rock found above them, rather than by tunneling underground.

Surface Mining—A synonym for strip mining.

Thermal Pollution—Harmful effects to the environment that may be produced by the warm water released by electric power plants into nearby lakes, rivers, or oceans.

Thermonuclear Fusion—See *fusion.*

Wastes, Radioactive—A by-product of producing power by splitting atoms in a nuclear power plant; some of these materials are highly radioactive and stay radioactive for long periods of time.

Watt—See *kilowatt.*

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–NOTES–

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